DECLARATION

I, SHINICHI USUI, a Japanese Patent Attorney registered No. 9694, of Okabe International Patent Office at No. 602, Fuji Bldg., 2-3, Marunouchi 3-chome, Chiyoda-ku, Tokyo, Japan, hereby declare that I have a thorough knowledge of Japanese and English languages, and that the attached pages contain a correct translation into English of the priority documents of Japanese Patent Application No. 11-024968 filed on February 2, 1999 in the name of CANON KABUSHIKI KAISHA.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made, are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 11th day of December, 2000

SHINICHI USUI

PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

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Semiconductor Device, Solar Cell Module and Methods for Their Dismatlement

[WHAT IS CLAIMED IS]

[Claim 1]

A semiconductor device comprising a substrate, sealant and a semiconductor element, wherein the semiconductor element is separable from the substrate.

[Claim 2]

The semiconductor device according to claim 1, which is separable into a laminate having the semiconductor element, and the substrate.

[Claim 3]

The semiconductor device according to claim 1, which further comprises a protective layer, and is separable into a laminate having the semiconductor element, and the protective layer.

[Claim 4]

The semiconductor device according to claim 1, which further comprises an exfoliative layer.

[Claim 5]

The semiconductor device according to claim 4, wherein the exfoliative layer comprises a thermoplastic

resin.

[Claim 6]

The semiconductor device according to claim 5, wherein the thermoplastic resin is of non-crosslinking.

[Claim 7]

The semiconductor device according to claim 4, wherein the exfoliative layer comprises a degradable resin.

[Claim 8]

The semiconductor device according to claim 4, wherin the exfoliative layer comprises a foam or a foam precursor.

[Claim 9]

A process for producing a semiconductor device having a substrate, a sealant and a semiconductor element; the process comprising the step of producing the semiconductor device in such a way that the semiconductor element is separable from the substrate.

[Claim 10]

A process for producing the semiconductor device according to claim 1, which comprises the step of producing the semiconductor device so as to be separable into a laminate having the semiconductor element, and the substrate.

[Claim 11]

A process for producing the semiconductor device according to claim 1, wherein the semiconductor device further has a protective layer, and which process comprises

the step of producing the semiconductor device so as to be separable into a laminate having the semiconductor element, and the protective layer.

[Claim 12]

A process for producing the semiconductor device according to claim 1, wherein comprises the step of producing the semiconductor device so as to have an exfoliative layer.

[Claim 13]

The process according to claim 12, wherein the exfoliative layer comprises a thermoplastic resin.

[Claim 14]

The process according to claim 13, wherein the thermoplastic resin is of non-crosslinking.

[Claim 15]

The process according to claim 12, wherein the exfoliative layer comprises a degradable resin.

[Claim 16]

The process according to claim 12, wherein the exfoliative layer comprises a foam or a foam precursor.

[Claim 17]

A method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising separating the semiconductor element from the substrate.

[Claim 18]

The method according to claim 17, which comprises

the step of heating the semiconductor device.

[Claim 19]

The method according to claim 17, which comprises the step of heating and moistening the semiconductor device.

[Claim 20]

The method according to claim 17, wherein the semiconductor device has an exfoliative layer, and the exfoliative layer is broken to separate constituent members.

[Claim 21]

The method according to claim 20, which comprises the step of irradiating the exfoliative layer with electron beam.

[Claim 22]

The method according to claim 20, wherein the semiconductor device has a form precursor, and the semiconductor device is heated to cause the foam precursor to form to form the exfoliative layer.

[Claim 23]

The method according to claim 17, wherein the semiconductor device further has a protective layer, and which method comprises the step of removing the sealant remaining on the surface and/or back of the semiconductor element after separating the protective layer and/or substrate of the semiconductor device.

[Claim 24]

The method according to claim 23, wherein the sealant is removed with an acid, an alkali or an organic

solvent.

[Claim 25]

A solar celll module comprising a substrate, a sealant and a semiconductor element, wherein the photovoltaic element is separable from the substrate.

[Claim 26]

The solar cell module according to claim 25, which is separable into a laminate having the photovoltaic element, and the substrate.

[Claim 27]

The solar cell module according to claim 25, which is separable into a laminate having the photovoltaic element, and the protective layer.

[Claim 28]

The solar cell module according to claim 25, which further comprises an exfoliative layer.

[Claim 29]

The solar cell module according to claim 28, wherein the exfoliative layer comprises a thermoplastic resin.

[Claim 30]

The solar cell module according to claim 29, wherein the thermoplastic resin is of non-crosslinking.

[Claim 31]

The solar cell module according to claim 28, wherein the exfoliative layer comprises a degradable resin.

[Claim 32]

The solar cell module according to claim 28, wherein the exfoliative layer comprises a foam or a foam precursor.

[Claim 33]

A process for producing a solar cell module having a substrate, a sealant, a photovoltaic element and a protective layer; the process comprising the step of producing the solar cell module in such a way that the photovoltaic element is separable from the substrate.

[Claim 34]

The process according to claim 33, which comprises the step of producing the solar cell module so as to be separable into a laminate having the photovoltaic element, and the substrate.

[Claim 35]

The process according to claim 33, which comprises the step of producing the solar cell module so as to be separable into a laminate having the photovoltaic element, and the protective layer.

[Claim 36]

The process according to claim 33, which comprises the step of producing the solar cell module so as to have an exfoliative layer.

[Claim 37]

The process according to claim 36, wherein the exfoliative layer comprises a thermoplastic resin.

[Claim 38]

The process according to claim 37, wherein the thermoplastic resin is of non-crosslinking.

[Claim 39]

The process according to claim 36, wherein the exfoliative layer comprises a degradable resin.

[Claim 40]

The process according to claim 36, wherein the exfoliative layer comprises a foam or a foam precursor.

[Claim 41]

A method of dismantling a solar cell module having a substrate, a sealant, a photovoltaic element and a protective layer; the method comprising separating the photovoltaic element from the substrate.

[Claim 42]

The method according to claim 41, which comprises the step of heating the solar cell module.

[Claim 43]

The method according to claim 41, which comprises the step of heating and moistening the solar cell module.

[Claim 44]

The method according to claim 41, wherein the solar cell module has an exfoliative layer, and the exfoliative layer is broken to separate constituent members.

[Claim 45]

The method according to claim 44, which comprises the step of irradiating the exfoliative layer with electron beam.

[Claim 46]

The method according to claim 44, wherein the solar cell module has a foam precursor, and the solar cell module is heated to cause the foam precursor to foam to form the exfoliative layer.

[Claim 47]

The method according to claim 41, which comprises the step of removing the sealant remaining on the surface and/or back of the photovoltaic element after separating the protective layer and/or substrate of the solar cell module.

[Claim 48]

The method according to claim 47, wherein the sealant is removed with an acid, an alkali or an organic solvent.

[Claim 49]

A semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by heating the semiconductor device.

[Claim 50]

A semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by heating and moistening the semiconductor device.

[Claim 51]

A semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by irradiating the semiconductor device with electron beam.

[Claim 52]

A semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by immersing the semiconductor device in a liquid.

[Claim 53]

A solar cell module comprising a substrate, a sealant and a photovoltaic element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by heating the solar cell module.

[Claim 54]

A solar cell module comprising a substrate, a sealant and photovoltaic element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by heating and moistening the solar cell module.

[Claim 55]

A solar cell module comprising a substrate, a sealant and a photovoltaic element, wherein at least one of

the substrate, the sealant and the photovoltaic element is separable from the other constituent members by irradiating the solar cell module with electron beam.

[Claim 56]

A solar cell module comprising a substrate, a sealant and a photovoltaic element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by immersing the solar cell module in a liquid.

[Claim 57]

A method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising heating the semiconductor device to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[Claim 58]

A method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising heating and moistening the semiconductor device to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[Claim 59]

A method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising irradiating the semiconductor device with electron beam to separate at least one of the

substrate, the sealant and the semiconductor element from the other constituent members.

[Claim 60]

A method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising immersing the semiconductor device in a liquid to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Industrial Utilization]

This invention relates to a semiconductor device as exemplified by a solar cell module, which comprises a supporting substrate, a sealant and a semiconductor element as exemplified by a photovoltaic element.

[0002]

[Prior Art]

In recent years, solar cell modules are used in various purposes, one of which is a construction material integral type solar cell module comprising photovoltaic elements provided on a roofing steel sheet and covered with a sealant. In future, solar cell modules may become useless because of reconstruction of houses provided with solar cell modules as construction materials, or it may become necessary that they are reroofed or exchanged

because of corrosion of metal substrates as a result of outdoor long-term service or because of cracks produced in surface members on the light-receiving side. Thus, when solar cell modules having become useless are discarded, we are anxious about environmental pollution unless individual constituent members are separated from one another and sorted so as to be discarded properly, and it has become required for solar cell modules to be separable by individual constituent members. From the viewpoint of ecology, it is also required for them to be dismantled into utilizable members and to be reused. Japanese Patent Application Laid-Open No. 9-45951 discloses a peelable adhesive layer provided in a solar cell on its light-receiving side.

[0003]

[Problems to be solved by the Invention]

In the prior art, no proposal has been made on a specific method by which solar cell modules are dismantled into the photovoltaic element and the substrate and the reusable member(s) are reused. The present invention provides a solar cell module from which reusable members can be separated and a method for dismantling such a solar cell module.

[0004]

[Means for solving the Problems]

In order to solve the above problems, the present invention provides a semiconductor device comprising a

substrate, a sealant and a semiconductor element, wherein the semiconductor element is separable from the substrate.

[0005]

The present invention provides a method for producing a semiconductor device having a substrate, a sealant and a semiconductor element, comprising the step of producing the semiconductor device in such a way that the semiconductor element is separable from the substrate.

[0006]

The present invention provides a method for dismantling a semiconductor device having a substrate, a sealant and a semiconductor element, comprising separating the semiconductor element from the substrate.

[0007]

The present invention provides a solar cell module a substrate, a sealant and a photovoltaic element, wherein the photovoltaic element is separable from the substrate.

[0008]

The present invention provides a process for producing a solar cell module having a substrate, a sealant, a photovoltaic element and a protective layer; the process comprising the step of producing the solar cell module in such a way that the photovoltaic element is separable from the substrate.

[0009]

The present invention procides a method of dismantling a solar cell module having a substrate, a

sealant, a photovoltaic element and a protective layer; the method comprising separating the photovoltaic element from the substrate.

[0010]

The present invention provides a semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by heating the semiconductor device.

[0011]

The present invention provides a semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by heating and moistening the semiconductor device.

[0012]

The present invention provides a semiconductor device comprising a substrate, a sealant and a semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by irradiating the semiconductor device with electron beam.

[0013]

The present invention provides a semiconductor device comprising a substrate, a sealant and a

semiconductor element, wherein at least one of the substrate, the sealant and the semiconductor element is separable from the other constituent members by immersing the semiconductor device in a liquid.

[0014]

The present invention provides a solar cell module comprising a substrate, a sealant and a photovoltaic element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by heating the solar cell module.

[0015]

The present invention provides a solar cell module comprising a substrate, a sealant and a photovoltaic element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by heating and moistening the solar cell module.

[0016]

The present invention provides a solar cell module comprising a substrate, a sealant and a photovoltaic element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by irradiating the solar cell module with electron beam.

[0017]

The present invention provides a solar cell module comprising a substrate, a sealant and a photovoltaic

element, wherein at least one of the substrate, the sealant and the photovoltaic element is separable from the other constituent members by immersing the solar cell module in a liquid.

[0018]

The present invention provides a method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising heating the semiconductor device to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[0019]

The present invention provides a method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising heating and moistening the semiconductor device to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[0020]

The present invention provides a method of dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising irradiating the semiconductor device with electron beam to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[0021]

The present invention provides a method of

dismantling a semiconductor device having a substrate, a sealant and a semiconductor element; the method comprising immersing the semiconductor device in a liquid to separate at least one of the substrate, the sealant and the semiconductor element from the other constituent members.

[0022]

[Operation]

(1) After constituent members are separated from semiconductor devices as exemplified by solar cell modules, still serviceable constituent members can be recovered and reused. Stated more specifically, if by some chance a problem on product use has occurred at some place as a result of long-term outdoor service, any constituent member(s), in particular, semiconductor elements as exemplified by photovoltaic elements, having caused the problem can be separated from substrates, and any still serviceable remaining constituent members such as semiconductor elements can be recovered and reused.

(2) Supporting substrates can be separated from solar cell modules which must otherwise be discarded because of corrosion of supporting substrates made of metal or because of break of supporting substrates made of glass, and hence such substrates can be changed for new ones so that the modules can be reused.

(3) Protective layers can be separated from solar cell modules which must otherwise be discarded because of scratches made in protective layers, and hence new

protective materials can be set so that the module can be reused.

(4) Since the exfoliative layer can be provided at any desired position, constituent members can be separated from solar cell modules with ease by a given operation.

(5) Since the exfoliative layer can be formed of a thermoplastic resin, the solar cell module can be dismantled into the laminate including the protective layer and the photovoltaic element, and the supporting substrate.

(6) Since the exfoliative layer can be provided as a degradable resin layer, the uppoer and lower constituent members interposing the exfoliative layer can be separated with ease. For example, the resin can be degraded by irradiation with electron beam, or, as another means, can be degraded by biochemical decomposition.

(7) Since a foam can be provided as the exfoliative layer, the upper and lower constituent members interposing the exfoliative layer can be separated with ease. For example, the form has a small area of adhesion to the adjoining constituent members and has a low adhesion thereto, and hence can be separated at interface with ease. Since also the foam encloses gas internally, the cohesive failure takes place in the foam with easse. Thus, the upper and lower constituent members interposing the foam can be separated with ease.

[0023]

[Mode for carrying out the Invention]

An example of a semiconductor element such as a solar cell module used in the present invention will be described below with reference to (a) and (b) of Fig. 1. (a) of Fig. 1 illustrates a film type solar cell module in which a transparent film is used at the outermost surface. (b) of Fig. 1 illustrates a glass type solar cell module in which a glass sheet is used at the outermost surface. Reference numeral 101 denotes a photovoltaic element (in plurality); 102, a surface-side sealant; 103, a protective layer; 104, a back-side sealant; 105, a back insulating material; and 106, a supporting substrate (a back member). As the photovoltaic element (in plurality) 101, conventionally known photovoltaic elements may appropriately be used. Reference numerals 101 to 106 denote constitutional members that make up a solar cell module. The photovoltaic elements are embedded in the module without leaving any vacancies, by at least one of the surface-side sealant and back-side sealant detailed below.

[0024]

(Surface-side Sealant 102)

The surface-side sealant 102 covers unevenness of the photovoltaic elements 101, protects the photovoltaic elements 101 from severe external environment such as temperature changes, humidity and impact and also ensures adhesion between the protective layer 103 and the photovoltaic elements 101. This surface-side sealant 102

is required to have weather resistance adhesion, fill performance, heat resistance, cold resistance and impact resistance. Resins that can meet these requirements may include polyolefin resins such as ethylene-vinyl acetate copolymer (EVA), ethylene-methyl acrylate copolymer (EMA), ethylene-ethyl acrylate copolymer (EEA) and butyral resin, urethane resins, and silicone resins. In particular, EVA is a resin used preferably as a resin for solar cells. This EVA may preferably be crosslinked beforehand to increase the heat distortion temperature so as to have a higher thermal resistance. As cross-linking agents used in such an instance, known organic peroxides may be used, any of which may be added in an amount of from 0.5 to 5 parts weight based on 100 parts by weight of the resin. The surface-side sealant 102 may preferably be cross-linked by at least 70%. Even in the case that the crosslinked sealant has a thermal resistance to about 120 °C, it preferably has such properties that it softens by heating of 200 °C or higher, that is, the sealant preferably has such properties that it has a thermal resistance to a given temperature but softens at a temperature of higher than a given temperature. More preferred is a sealant which, once it softens, comes to have a low adhesion to a constituent member adjoining to the sealant. Use of such a sealant makes it possible to separate constituent members by heating, between the constituent members interposing the sealant. Specific materials therefor may include

polyolefin resins such as ethylene-vinyl acetate copolymer (EVA), ethylene-methyl acrylate copolymer (EMA), ethylene-ethyl acrylate copolymer (EEA) and butyral resin, and ionomer resins. In the present invention, this surface-side sealant may also be made separable.

[0025]

(Protective Layer 103)

The protective layer 103 is required performances for ensuring long-term reliability during outdoor weathering of the solar cell module, including weather resistance and mechanical strength. Materials for this protective layer 103 may include fluororesins, acrylic resins, poly(vinyl fluoride) resin (PVF), poly(ethylene terephthalate) (PET) and nylon. Stated specifically, in the case of a film type solar cell module, it is preferable to use poly(vinylidene fluoride) resin (PVDF), poly(vinyl fluoride) resin (PVF) or tetrafluoroethylene-ethylene copolymer (ETFE); and, in the case of a glass type solar cell module, poly(vinyl fluoride) (PVF) as having a high weather resistance.

[0026]

The above resin sheet may be bonded to the sealant 102 to form the protective layer, or the above resin in a liquid state may be coated to form the protective layer.

[0027]

(Back Insulating Material 105)

The back insulating material 105 is necessary for

keeping electrical insulation between the photovoltaic elements 101 and the exterior. Preferable materials are those having sufficient electrical insulating properties, having a superior long-term durability, able to withstand thermal expansion and thermal shrinkage, and having a flexibility also. Materials preferably usable may include nylon, poly(ethylene terephthalate) (PET) and polycarbonate (PC).

[0028]

(Back-side Sealant 104)

The back-side sealant 104 can make the photovoltaic elements 101 adhere to the back insulating material 105. Materials therefor may include thermoplastic resins such as EVA, ethylene-methyl acrylate copolymer (EMA), ethylene-ethyl acrylate copolymer (EEA) and poly(vinyl butyral), and epoxy adhesives having a flexibility, any of which may preferably be in the form of a double-coated tape. In the present invention, the semiconductor element is separable from the substrate at this back-side sealant. In the case that at least one of the substrate and the semiconductor element deteriorates and has to be changed for new one, the reusable member can be reused and the non-reusable member can be disposed with ease. As a result, the cost can be reduced or the working efficiency can be improved. Further, the back-side sealant itself may be an exfoliative layer described later.

[0029]

(Supporting Substrate 106)

The supporting substrate (back-side member) 106 can make the solar cell module have a higher mechanical strength, or can prevent its distortion or warpage caused by temperature changes. The supporting substrate 106 is also attached in order to set up a roofing material integral type solar cell module. As the supporting substrate 106, preferred are, e.g., coated steel sheets such as aluminum-coated galvanized steel sheets or galvanized steel sheets, covered with resins having superior weather resistance and rust resistance, and structural materials such as plastic sheets and glass-fiber-reinforced plastic sheets. In particular, as the coated steel sheets, preferably usable are those in which a hydrated chromium oxyhydroxide layer is provided between the steel sheet and the coating film for the purpose of rust-resisting treatment. This is because, under severe heated and moistened conditions, e.g., under conditions of 150°C and 100%RH (relative humidity), hydrated chromium oxyhydroxide melts out and becomes deposited to form a vacancy between the stell sheet and the coating film. Such a vacant layer between the steel sheet and the coating film may be utilized to separate the constituent members. In the present invention, the semiconductor element as exemplified by the photovoltaic element can be separated from the substrate (supporting substrate 106). The constituent member can be changed for new one with ease

whichever member has deteriorated, the substrate or the semiconductor element, and has to be changed for new one. Hence, constituent members which are still serviceable can be reused and even constituent members which are no longer serviceable can be discarded with ease. As the result, cost reduction can be achieved or operating efficiency can be improved. Moreover, in such an instance, the semiconductor element, which is surrounded by the back-side sealant, can be changed for new one with east without its exposure to the open air even when the structural material is separated.

[0030]

In the case of the glass type solar cell module, a glass substrate may preferably be used.

[0031]

(Surface Protection Reinforcing Material 107)

The surface protection reinforcing material 107 may specifically include glass-fiber nonwoven fabric, glass-fiber woven fabric and glass fillers. In particular, it is preferable to use glass-fiber nonwoven fabric. This surface protection reinforcing material 107 can protect the photovoltaic elements from scratches of the light-receiving surfaces thereof. In the present invention, the surface protection reinforcing material 107 may be provided, if necessary.

[0032]

The step of lamination to form the solar cell

module will be described below.

[0033]

(Lamination)

To produce the film type solar cell module by lamination, the supporting substrate 106, the back-side sealant 104, the back insulating material 105, the back-side sealant 104 are superposed in this order, and then the photovoltaic elements 101 are laminated thereon with their light-receiving sides up. Further thereon, the surface protection reinforcing material 107, the surface-side sealant 102 and the protective layer 103 are superposed in this order so as to seal the photovoltaic elements 101 and the surface protection reinforcing material 107. A lamination structure thus formed may be heated and contact-bonded by means of a conventionally known vacuum laminator. The heating temperature and heating time at the time of the contact bonding may be determined so that the cross-linking reaction of the sealant resin may proceed sufficiently.

[0034]

The solar cell module thus produced is dismantled by separating any desired constituent members at their interface. Methods therefor may include a method in which the constituent members are separated by heating, a method in which they are separated by heating and moistening, a method in which they are separated by boiling, a method in which the solar cell module is immersed in a solvent to cause the sealant to swell to effect separation, and a

method in which the constituent members are separated by irradiating with electron beam. In particular, the separation by heating, the separation by heating and moistening, the separation by irradiating with electron beam, and the separation by immersing in solvent (liquid) may preferably be used. Thus, the semiconductor device such as the solar cell module of the present invention has characteristics that it has a high mechanical strength under environment normally used and is easily separable under a constant condition. As an example of the dismantling method of the present invention, a method in which constituent members having EVA are separated will be described below, giving an example in which EVA is used as the sealant of the solar cell module.

[0035]

(1) Separation of constituent members by heating:

The lamination to produce the solar cell module is commonly carried out at a temperature in the range of from 100 to 180°C, and preferably from 120 to 160°C. This is because, if the temperature is below 100°C, the EVA can not melt well, in other words, can not provide a good fluidity, so that the unevenness on the photovoltaic elements can not be filled up, and also, if it is above 180°C, there is a possibility that the solder used to make connection between photovoltaic elements and their connection with bypass diodes may melt to cause faulty electrical connection. In addition, solar cell modules may come to have a module

surface temperature of 85°C during sunshine. In order to achieve long-term reliability for 20 years or longer in such environment, materials having substantially a resistance to heat of about 120°C are used as the EVA used in solar cell modules. Accordingly, in order to cause the EVA to soften so as to decrease the adhesion to the adjoining other constituent members, the EVA is heated to 130°C or above, during which an external peel force may be applied between the constituent members interposing the EVA, whereby the constituent members can be separated from the solar cell module with ease. Thus, in the present invention, the constituent members can easily be separated at a desired position by heating the constituent members. Further, when the sealant has a low thermal resistance, the heating temperature for exfoliating may be set lower.

[0036]

(2) Separation of constituent members by heating and moistening:

EVA hydrolyzes under heated and moistened conditions of, e.g., 150°C and 100%RH. As a result of hydrolysis, the EVA decreases in its adhesion to the constituent member such as the supporting substrate or the protective layer. This decrease in adhesion of the EVA to other constituent member is utilized so that the EVA can be separated from other constituent members with ease. Thus, in the present invention, the desired constituent member can be separated from the solar cell module by heating and

moistening the constituent members. Needless to say, the higher the values for temperature and humidity conditions are, the more the hydrolysis is accelerated. Application of pressure to the atmosphere also accelerates the progress of water into the solar cell module. Such pressure may preferably be applied under conditions of at least 2 atmospheric pressure, and more preferably at least 5 atmospheric pressure.

[0037]

According to the present invention, any of the above methods makes it possible to separate the protective layer 103, the surface protection reinforcing material 107 and the back insulating material 105 and thereafter to remove the surface-side sealant 102 or back-side sealant 104 remaining on the surface or back of the photovoltaic elements 101, so that only the photovoltaic elements 101 can be reused. According to the present invention, it is also possible to separate resin materials from metal materials to discard them. It is still also possible to remove the sealant resin such as EVA remaining on the surfaces of the photovoltaic elements, which can be removed using an acid such as nitric acid, or an alkali or organic solvent, heated to, e.g., 50°C or above.

[0038]

(Exfoliative Layer)

The constituent members can be separated with ease by providing an exfoliative layer made of, for example, a

thermoplastic resin, a degradable resin or a foam to the solar cell module described above. The exfoliative layer preferably is provided at the position to be separated in the solar cell module. In addition, the exfoliative layer may be used in the place of the sealant irrespective of the surface-side or the back-side of the photovoltaic elements. An exfoliative layer preferably usable will be described below.

[0039]

A thermoplastic resin may be provided as the exfoliative layer. This enables easy separation of constituent members by heating. As the thermoplastic resin, the same resin as the resin used in the surface-side sealant may preferably be used. Taking account of reuse of the constituent members obtained by separation, it is preferable not to apply stress such as heat history as far as possible when the constituent members are separated by heating. Stated specifically, a thermoplastic resin which does not cross-link may be used to provide the exfoliative layer, whereby the constituent members can be separated at a temperature lower than the instance where the constituent members are separated at the part of the sealant. In the case where the thermoplastic resin is provided as the exfoliative layer, the constituent members can be separated at a temperature of 150°C or below. For example, when non-crosslinked EVA is provided as the exfoliative layer, the constituent members can be separated at a temperature of

from 10 to 120°C. Transparent thermoplastic resins such as EVA can be provided at any position because it by no means lowers the quantity of electricity generation of the solar cell module even when provided on the photovoltaic elements. In order to ensure the long-term reliability, an ultraviolet light absorber, a photostabilizer and an antioxidant may also be added as in the case of the surface-side sealant. Thus, the heating temperature for exfoliation can be set lower by providing the exfoliative layer made of a thermoplastic resin to the solar cell module.

[0040]

An instance where the degradable resin is provided as the exfoliative layer will be described below.

[0041]

Resins can be degraded (broken down) by a method including electron beam irradiation and biochemical means. Herein, degradation of resin by electron beam irradiation will be described, as being preferably usable. Electron beam are included in ionizing radiations, and are one of particle energy rays which excite organic materials to ionize them. Electron beam can be controlled by adjusting accelerating voltage, radiation dose, radiation dose rate and so forth. Electron beam are applied to the solar cell module on its light-receiving side to cause molecular chains in the resin to cut to degrade the resin. Thus, the constituent members can be separated with ease between

constituent members interposing the electron beam degradable resin layer thus degraded. Resins readily degradable by electron beam irradiation may include those having a chemical structure wherein ($-CH_2-CR_1-R_{2n}-$) or -CO- is repeated structurally. Stated specifically, resins having the structure of the repeating unit ($-CH_2-CR_1-R_{2n}-$) may include polyisobutylene, polymethylstyrene, polymethacrylate, polymethacrylonitrile and poly(vinylidene chloride). Resins having the structure of the repeating unit -CO- may include polycarbonate (PC), polyacetal and cellulose. The degradable resin may be not crosslinked. The above resin may be provided at any desired position. In the case where it is provided on the light-receiving side of the photovoltaic elements, it should be a transparent resin. In order to improve weather resistance, an ultraviolet light absorber and an antioxidant may also be added as in the case of the surface-side sealant. As methods for providing the electron beam degradable resin layer, the above resin may be coated on the part where constituent members are to be separated, e.g., on the supporting substrate. Alternatively, a film formed of the above resin may be provided at that part. Establishment of an accelerating voltage will be described below. The accelerating voltage necessary for electron beam to be transmitted through a substance becomes greater in inverse proportion to the specific gravity the substance has. For example, in order for electron beam to be transmitted

through a metal member having a specific gravity of 8, it is necessary to apply an accelerating voltage eight times that necessary for them to be transmitted through a resin having a specific gravity of 1. Accordingly, in the solar cell module described above, in an instance where the electron beam degradable resin layer is provided on the back of the photovoltaic elements, it is necessary to apply an accelerating voltage of at least 500 keV in order for electron beam to be transmitted through the photovoltaic elements to degrade the exfoliative layer on the back. This makes it necessary to provide large-scale equipment. In order to separate constituent members in relatively simple equipment, the degradable resin layer may preferably be provided on the photovoltaic elements in the case where the constituent members are separated at the exfoliative layer by electron beam irradiation. Taking account of the reuse of the photovoltaic elements separated, the electron beam may preferably be applied at an accelerating voltage of 300 keV or below. As another structure, a foam formed when the solar cell module is dismantled by heating may be used as the exfoliative layer. The foam can be formed by a chemical process in which a foam precursor prepared by mixing a resin and a blowing agent is heated to produce cells in the resin by the action of the decomposed gas of the blowing agent, or a physical process in which an inert gas is enclosed in the resin.

[0042]

First, a method will be described in which the foam is provided in the solar cell module by the chemical process.

[0043]

The foam precursor is provided in the solar cell module, between its constituent members to be separated, and, when the constituent members are separated, the foam precursor is heated to make the blowing agent decompose to form the foam by the action of the decomposed gas. The foam precursor has a large area of adhesion to the adjoining constituent members and hence has also a great adhesion, thus the foam precursor by no means causes any peeling at the interface between it and the constituent members. However, upon blowing, the area of adhesion to the constituent members adjoining to the foam formed becomes small abruptly to cause a decrease in adhesion, thus it becomes easy to separate the constituent members at their interfaces to the exfoliative layer. Also, since the interior of the foam has come to have a small cohesive force because of the cells mixedly present, it is easy to cause cohesive failure in the interior of the foam by external peel force. Further addition of heat enables more easy separation.

[0044]

For the purpose of maintaining the quality of the foam and preventing the interior of cells in the foam from sweating because of temperature changes, the step of

forming the foam may most preferably be so provided as to blow the foam precursor immediately before the constituent member are separated. Also, the blowing agent is required to have such heat decomposition properties that it is not decomposed at heating temperature at the time of the lamination for producing the solar cell module, i.e., at lamination temperature, but expands at heating temperature for separating the constituent members, i.e., at a temperature higher than the lamination temperature. For example, the blowing agent may include those having a decomposition temperature of 200°C or above, specifically including trihydrazinotriazine, p-toluenesulfonyl semicarbazide and 4,4'-oxybisbenzenesulfonyl semicarbazide. The resin in which the blowing agent is mixed is required to have a long-term reliability like other constituent members until the constituent members are right about to be separated, and is also required to have an adhesion strength between it and the supporting substrate adjuoining to the foam precursor or between it and the sealant. As specific materials, it may include natural rubber, styrene-butadiene rubber, chloroprene rubber, ethylene-propylene-diene rubber, and copolymers of ethylene with acrylic esters, such as ethylene-vinyl acetate and ethylene-ethyl acrylate copolymers.

[0045]

A foam may be subjected to moistureproofing or waterproofing treatment on its surroundings so that a foam

having already been formed can be provided in the solar cell module. At the time the laminate is produced by lamination, the foam precursor may be superposed at the desired position so that it is blown by the heat in the step of lamination to provide the foam in the solar cell module. As a blowing agent used in such an instance, it may include inorganic blowing agents such as sodium bicarbonate, ammonium bicarbonate and ammonium carbonate, and organic blowing agents such as nitroso compounds and sulfonic acid hydrazide compounds.

[0046]

The foam may also be disposed at any desired position of the laminate, followed by lamination to provide it as the exfoliative layer of the solar cell module.

[0047]

Such a foam can be formed by a method including a chemical means and a physical means.

[0048]

The chemical means is the same as the blowing means making use of the blowing agent described above. The physical means will be described below. The physical means is a method of forming a foam by injecting a gas into a resin. The resin used is required to have such a heat resistance that it does not melt by the heat applied in the step of lamination. Stated specifically, it may include poly(ethylene terephthalate), poly(ethylene naphthalenedicarboxylate), polyether sulfonate, polyimide,

polyimide-amide and polyether imide. The gas to be mixed may preferably be an inert gas such as nitrogen. The gas may be mixed into the resin by a known process such as cavity mixing or nozzle mixing. The solar cell module having such a foam can be dismantled by heating the solar cell module so that the resin used in the foam is caused to melt or soften to break the foam by the aid of pressure of the gas enclosed therein, thus the constituent members interposing the exfoliative layer can be separated.

[0049]

The foam or the foam precursor may be disposed between any constituent members. However, when the foam precursor is colored or has a low transparency, it may preferably be provided on the back of the photovoltaic elements.

[0050]

[Examples]

[Example 1]

Photovoltaic elements and other constituent members were laminated by the following lamination process to obtain a film type solar cell module.

[0051]

(Lamination)

On a plate of a laminator of a single vacuum system, a galvanized steel sheet (thickness: 0.4 mm) as a supporting substrate 206, an EVA sheet (thickness: 225 μm) as a back-side sealant 204, a poly(ethylene terephthalate)

film (thickness: 100 μm) as a back insulating material 205 and the same back-side sealant 204 as the above were superposed in this order and then photovoltaic elements 201 were put thereon with their light-receiving sides up. Further thereon, glass-fiber nonwoven fabric (basis weight: 80 g/m^2) as a surface protection reinforcing material 207, an EVA sheet (thickness: 460 μm) as a surface-side sealant 202 and an ETFE film (thickness: 50 μm) as a protective layer 203 were superposed in this order. Thus, a lamination structure was prepared. The EVA sheet used here was a sheet used widely as a sealant for solar cells, comprising EVA resin (vinyl acetate content: 33%) in 100 parts by weight of which 1.5 parts by weight of 2,5-dimethyl-2,5-bis(t-butylperoxy)hexane as a cross-linking agent, 0.3 part by weight of 2-hydroxy-4-n-octoxybenzophenone as an ultraviolet light absorber, 0.1 part by weight of bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate as a photostabilizer, 0.2 part by weight of tris(monononylphenyl) phosphite as an antioxidant and 0.25 part by weight of γ-methacryloxypropyltrimethoxysilane as a silane coupling agent were compounded. Next, a Teflon coated fiber sheet (thickness: 0.2 mm) and a silicone rubber sheet (thickness: 2.3 mm) were superposed on the lamination structure. Then, the inside of a laminator was evacuated for 30 minutes to a degree of vacuum of 2.1 Torr by means of a vacuum pump. The heating temperature and heating time at the time of contact bonding were so set

that the cross-linking reaction of the EVA resin proceeded sufficiently, where the laminator kept evacuated using the vacuum pump was put into an oven heated previously to have an atmosphere of 160°C and was kept there for 50 minutes. Thereafter, the laminate thus produced was taken out and cooled to obtain a solar cell module.

[0052]

(Separation)

The solar cell module was heated to 200°C, and a mechanical exfoliative force was applied between the supporting substrate 206 and the back-side sealant 204 while making the surface- and back-side sealants melt, thus a laminate 208 having the photovoltaic elements was separated from the supporting substrate 206. Next, an external exfoliative force was applied between the protective layer 203 and the surface-side sealant 202, thus the protective layer 203 was separated from the laminate 208 having the photovoltaic elements.

[0053]

[Example 2]

As follows, an exfoliative layer 309 was provided on a protective layer 303.

[0054]

(Formation of exfoliative layer)

An acrylic resin coating material (35 parts by weight of an acrylic resin composed chiefly of methacrylate, 3 parts by weight of

γ-glycidoxypropyltrimethoxysilane and 62 parts by weight of xylene) was coated on the protective layer 303 by means of a spray coater so as to have a thickness of 20 μm, and the wet coating formed was natural-dried at room temperature for 30 minutes to remove the solvent, followed by force-drying at 120°C for 30 minutes to form a protective layer having an exfoliative layer.

[0055]

A solar cell module was obtained in the same manner as in Example 1 except that the protective layer 303 was so superposed that the exfoliative layer 309 was on the side of a surface-side sealant 302.

[0056]

(Separation)

The solar cell module was irradiated by electron beam of 300 keV in a total dose of 50 Mrad on the light-receiving side of the solar cell module. Thereafter, external exfoliative force was applied between the protective layer 303 and surface-side sealant 302 interposing the exfoliative layer 309, thus the protective layer 303 was separated from the laminate 310 having the photovoltaic elements.

[0057]

[Example 3]

A solar cell module was obtained in the same manner as in Example 1 except that a foam precursor sheet formulated as shown below was superposed as an exfoliative

layer, between a supporting substrate and a back-side sealant. Fig. 4 is a schematic cross-sectional view of a solar cell module according to the present invention. In Fig. 4, reference numeral 411 denotes an exfoliative layer, 406 denotes a substrate, 404 denotes a back-side sealant, 405 denotes a back insulating material, 401 denotes photovoltaic elements, 407 denotes a surface protection reinforcing material and 403 denotes a protective layer.

[0058]

(Form Precursor Sheet)

100 parts by weight of ethylene-vinyl acetate resin (vinyl acetate: 15% by weight; melt flow rate: 9 dg/min), 40 parts by weight of soft calcium carbonate (primary particle diameter: about 3 μm) as a nucleating agent, 5 parts by weight of trihydrazinotriazine as a blowing agent, 1 part by weight of dicumyl peroxide as a cross-linking agent, 0.5 part by weight of stearic acid and 0.1 part by weight of carbon black as a pigment were mixed, and a sheet of 0.5 mm thick was prepared by means of an inverted L four-roll calender.

[0059]

(Separation)

The solar cell module was heated at 200°C for 1 hour. Thus, a solar cell module having an exfoliative layer, a foamed sheet, with a thickness of 1.2 mm was obtained. The module was broken at the part of the exfoliative layer, the foamed sheet, by external

exfoliative force, thus a laminate having the photovoltaic elements was separated from the supporting substrate.

[0060]

[Example 4]

A solar cell module was obtained in the same manner as in Example 1.

[0061]

(Separation)

The solar cell module was stored in an environment of 150°C, 100%RH and 5 atm pressure for 10 hours. Next, a mechanical exfoliative force was applied between the supporting substrate and the back-side sealant, thus a laminate having the photovoltaic elements was separated from the supporting substrate. Thereafter, an external exfoliative force was applied between the protective layer and the surface-side sealant, thus the protective layer was separated from the laminate having the photovoltaic elements.

[0062]

[Effect of the Invention]

In a semiconductor device according to the present invention, since the constituent members are separable from the substrate of the device, the constituent members can be reused and disposed with ease, thereby the working efficiency is improved and the cost of the device is reduced. In particular, in a solar cell module according to the present invention, if by some chance a problem on

product use has occurred at some place as a result of long-term outdoor service, only the constituent member(s) having caused the problem can be separated and the usable members can be recovered and reused. Also, since the exfoliative layer may be formed of a thermoplastic resin, the laminate portion can be separated from the supporting substrate by heating. In addition, since the exfoliative layer may be provided as a degradable resin layer or a foam, the constituent members can be separated with ease by a given means.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

(a) of Fig. 1 is a cross-sectional view of a film type solar cell module of the present invention.

(b) of Fig. 1 is a cross-sectional view of a glass type solar cell module of the present invention.

[Fig. 2]

Fig. 2 illustrates a method of dismantling a solar cell module by heating according to the present invention, as shown in Example 1.

[Fig. 3]

Fig. 3 illustrates a method of dismantling a solar cell module with an exfoliative layer 309 by electron beam according to the present invention, as shown in Example 2.

[Fig. 4]

Fig. 4 illustrates a method of dismantling a solar

cell module with a foam precursor sheet 407 by heating according to the present invention, as shown in Example 3.

[Description of Reference Numerals or Symbols]

100 ... incident light

101, 201, 301, 401 ... photovoltaic elements

102, 202, 302, 402 ... surface-side sealant

103, 203, 303, 403 ... protective layer

104, 204, 304, 404 ... back-side sealant

105, 205, 305, 405 ... back insulating material

106, 206, 306, 406 ... supporting substrate

107, 207, 307 ... surface protection reinforcing material

208, 310, 408 ... laminate

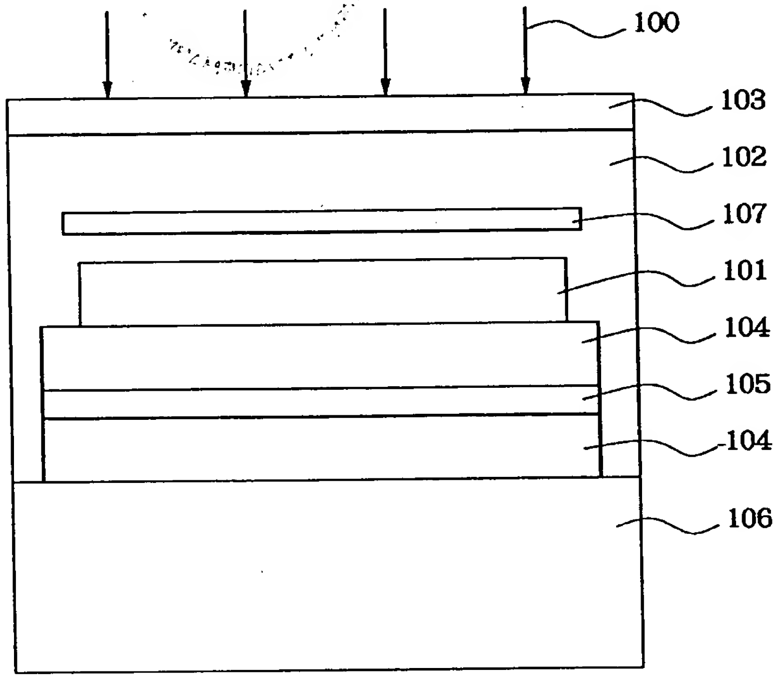
309 ... exfoliative layer

407 ... foam precursor sheet

【書類名】 図面

【図１】

(a)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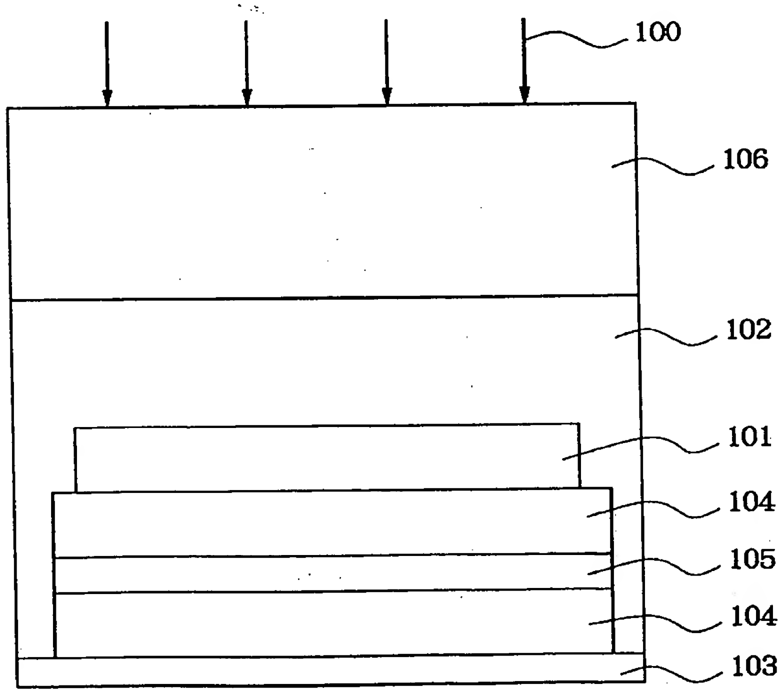
103
102
107
101
104
105
104
106

(b)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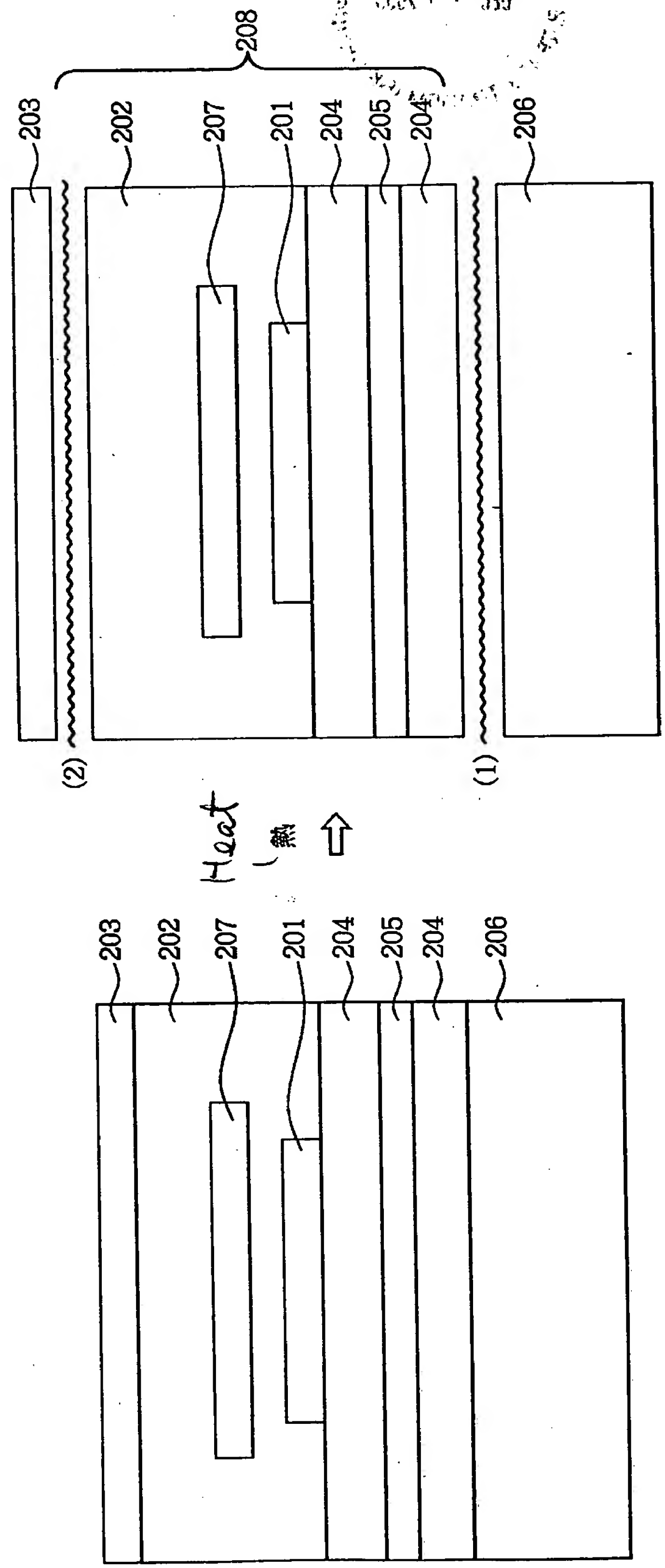
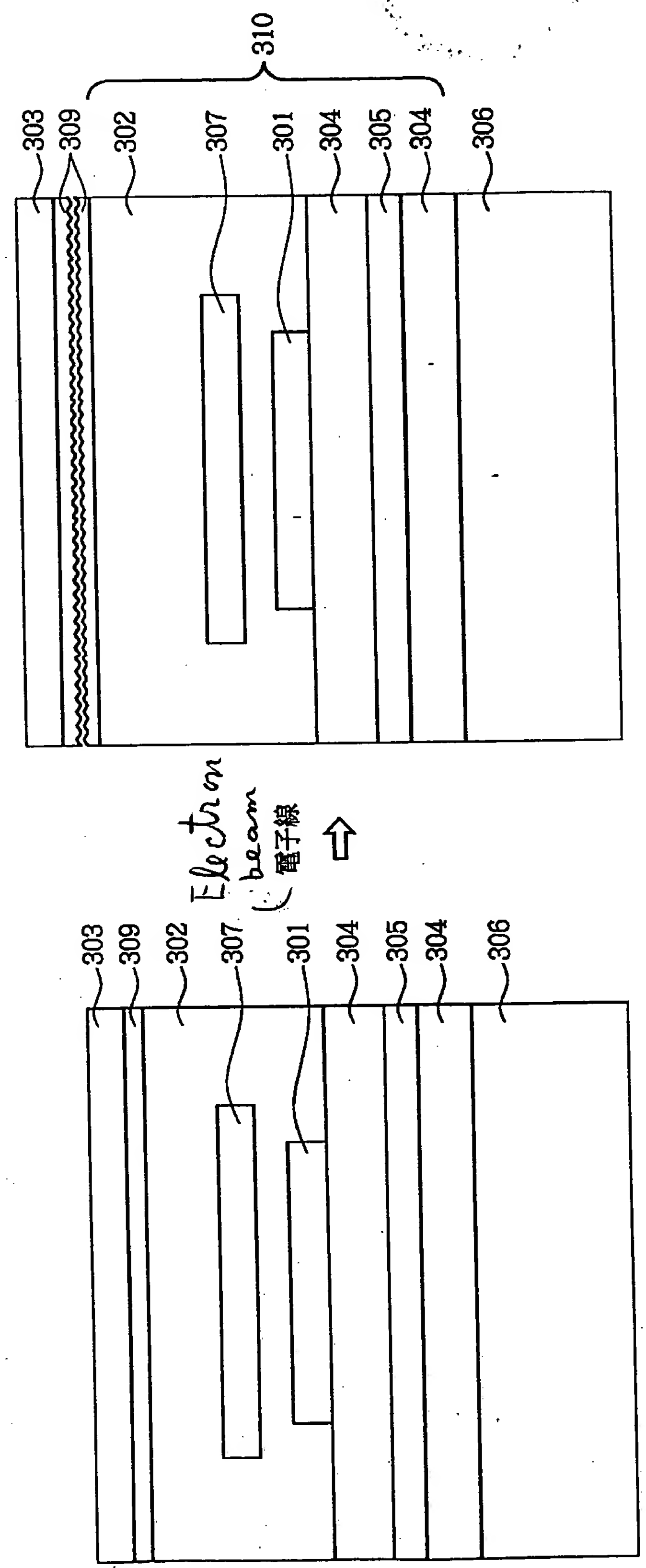
106
102
101
104
105
104
103

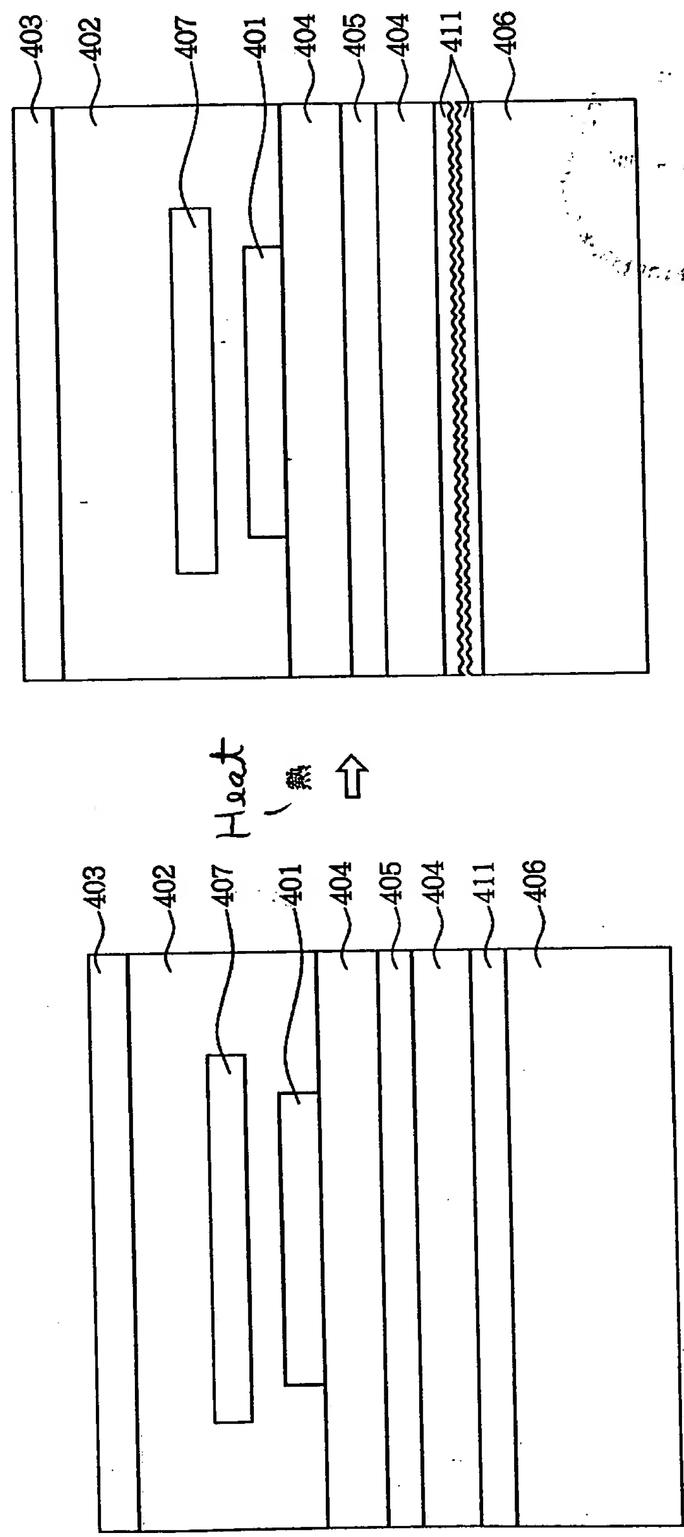
【図２】 Fig. 2


208
203
202
207
201
204
205
204
206
(2)
(1)
Heat
熱
203
202
207
201
204
205
204
206

【図３】 Fig. 3


310
303
309
302
307
301
304
305
304
306
Electron beam
電子線
303
309
302
307
301
304
305
304
306

【図４】 Fig. 4


403
402
407
401
404
405
404
411
406
Heat
熱
403
402
407
401
404
405
404
411
406

[NAME OF THE DOCUMENT] Abstract

[Abstract]

[Problem]

Provision of a semiconductor device such as a solar cell module in which reusable constituent members can be separated and a method for dismantling such a semiconductor device.

[Means for solving the Problem]

A solar cell module comprising a substrate 206, a sealant 202, a photovoltaic element(s) 201, and a protective layer 203, characterized in that at least one of said substrate, sealant, photovoltaic element(s) and protective layer can be separated from other constitutional members.

[Elected Drawing] Fig. 2